PAB Pesquisa Agropecuária Brasileira

ISSN 1678-3921

Journal homepage: www.embrapa.br/pab

For manuscript submission and journal contents, access: www.scielo.br/pab

Pomology/ Original Article

Fruit yield and water productivity of 'Prata Anã' banana under different planting densities and irrigation depths

Abstract – The objective of this work was to determine the fruit yield and water productivity of the 'Prata Anã' banana plant, under different combinations of planting densities and irrigation depths in its fourth production cycle. The experiment was designed in randomized complete blocks in a split-plot arrangement with four replicates, with the following factors: two levels of irrigation depth (50 and 100% crop evapotranspiration) in the plots and four levels of planting density (1,666, 2,083, 2,666, and 3,333 plants per hectare) in the subplots. Crop evapotranspiration and yield characteristics were evaluated. Reductions in the mass of hands, number of hands, and number of fruits were observed as planting density increased, as well as increments in the yield of hands and in water productivity and a reduction in water footprint. It is possible to increase the yield of the banana plant by increasing its planting density and reducing the irrigation depth applied in its fourth production cycle.

Index terms: *Musa*, water balance, yield.

Produtividade de frutos e da água em bananeira 'Prata Anã' sob diferentes densidades de plantio e lâminas de irrigação

Resumo – O objetivo deste trabalho foi determinar a produtividade de frutos e da água em bananeira 'Prata Anã', sob diferentes combinações de densidades de plantio e lâminas de irrigação no seu quarto ciclo de produção. O experimento foi delineado em blocos ao acaso, em arranjo de parcelas subdivididas, com quatro repetições, com os seguintes fatores: dois níveis de lâmina de irrigação (50 e 100% da evapotranspiração da cultura) nas parcelas e quatro níveis de densidade de plantio (1.666, 2.083, 2.666 e 3.333 plantas por hectare) nas subparcelas. Foram avaliadas a evapotranspiração e as características de produtividade da cultura. Foram observadas reduções na massa de pencas, no número de pencas e no número de frutos à medida que aumentou a densidade de plantio, bem como incrementos no rendimento de pencas e na produtividade hídrica e redução na pegada hídrica. É possível aumentar a produtividade da bananeira ao aumentar sua densidade de plantio e reduzir a lâmina de irrigação aplicada no seu quarto ciclo de produção.

Termos para indexação: *Musa*, balanço hídrico, produtividade.

Introduction

Water deficit is one of the environmental changes that can affect the performance and yield of agricultural crops in several regions

Leonardo Fernandes Barbosa[1 ✉],
Sérgio Luiz Rodrigues Donato[1],
Marcelo Rocha dos Santos[1] and
Eugênio Ferreira Coelho[2]

[1] Instituto Federal de Educação, Ciência e Tecnologia Baiano, Campus Guanambi, Zona Rural, Distrito de Ceraíma, CEP 46430-000 Guanambi, BA, Brazil. E-mail: leonardobarbosa.agr@hotmail.com, sergio.donato@ifbaiano.edu.br, marcelo.rocha@ifbaiano.edu.br

[2] Embrapa Mandioca e Fruticultura, Rua Embrapa, s/nº, Chapadinha, Caixa Postal 007, CEP 44380-000 Cruz das Almas, BA, Brazil. E-mail: eugenio.coelho@embrapa.br

✉ Corresponding author

Received
June 19, 2023

Accepted
February 29, 2024

How to cite
BARBOSA, L.F.; DONATO, S.L.R.; SANTOS, M.R. dos; COELHO, E.F. Fruit yield and water productivity of 'Prata Anã' banana under different planting densities and irrigation depths. **Pesquisa Agropecuária Brasileira**, v.59, e03423, 2024. DOI: https://doi.org/10.1590/S1678-3921.pab2024.v59.03423.

worldwide (Santos et al., 2022). In the semiarid region, an efficient water use should be a prioritized due to the low rainfall levels and consequent low water availability. In this scenario, precision in irrigation becomes preponderant to increase water use efficiency and reduce water footprint in crop production (Coelho et al., 2021; Souza et al., 2021).

In the semiarid region, specifically in the case of banana plantations, an important strategy used to reduce soil water evaporation and increase water productivity, consequently increasing yield, is increasing planting density, whose main aim is to protect the crop against wind and excess radiation, reduce weed emergence and herbicide use, and improve plant cooling capacity (Donato et al., 2015).

However, high densities may increase the time to flowering and harvesting (Santos et al., 2019; Magalhães et al., 2020). Athani et al. (2009) concluded that the increase in the number of plants per unit area negatively affects production per plant and percentage of harvested plants, which influences growth factors and total yield. Therefore, the best planting density should be adjusted considering cultivar characteristics, soil type, the climatological factors of the region, crop management, and production destination and intended longevity, as well as the association between technologies that allow of increasing yield and water use efficiency.

The effects of planting densities and irrigation depths have been evaluated in the first and second production cycles of 'Prata Anã' banana and in the first production cycle of 'BRS Platina' banana by Magalhães et al. (2020) and Santos et al. (2019), respectively. These factors are generally analyzed in these two cycles of the banana crop, because, as the plant increases in size, positive responses are not expected with an increased planting density in the successive cycles. Therefore, studies on the interaction of planting density and irrigation depths in later production cycles are still scarce in the literature.

The objective of this work was to determine the fruit yield and water productivity of 'Prata Anã' banana, under different combinations of planting densities and irrigation depths in its fourth production cycle.

Materials and Methods

The experiment was conducted in an area of Instituto Federal de Educação, Ciência e Tecnologia Baiano, located in the irrigated perimeter of Ceraíma, in the municipality of Guanambi, in the state of Bahia, Brazil (14º17'39.94S, 42º41'41.12W, at an altitude of 546 m). According to Köppen's classification, the climate of the region is mostly BSwh, semiarid, hot and dry, with a well-defined dry season in the winter and rainy season from October to March. Over a period of 40 years, the average annual rainfall was 672 mm and the average annual temperature was 26ºC. For the experimental period, the total rainfall and reference evapotranspiration (ETo) recorded were 424 and 2,061 mm, respectively (Figure 1).

The soil of the area is a Latossolo Vermelho-Amarelo with medium texture (Santos et al., 2018), which corresponds to an Oxisol (Soil Survey Staff, 2014). The physical characteristics of the soil were: bulk density of 1.60 kg dm^{-3}, 0.64 kg kg^{-1} sand, 0.15 kg kg^{-1} silt, and 0.21 kg kg^{-1} clay. The water contents were 0.20 and 0.11 m^3 m^{-3} at -10 and -1,500 kPa, respectively.

The experimental design was randomized complete blocks, in a split-plot arrangement, with four replicates. The tested factors were: two levels of irrigation depth (50 and 100% crop evapotranspiration, ETc) in the plots; and four levels of planting density (1,666, 2,083, 2,666, and 3,333 plants per hectare) in the subplots, spaced at 3.0x2.0, 3.0x1.6, 3.0x1.25, and 3.0x1.0 m, respectively. Irrigation management was based on ETc, determined by the ETo according to Allen et al. (1998) and the crop coefficient (Borges et al., 2011). Each planting density received the same irrigation depth of 100 or 50% ETc through micro-sprinklers with overlapping wetted areas, considering gross depth and emitter application intensity in the application of water. The emitter flow rate was 120 L h^{-1}, with an application intensity of 5.0 mm h^{-1} and spacing of 4.0 m between emitters and 6.0 m between lateral lines.

Although the evaluations were carried out in the fourth production cycle of the banana crop, the treatments were applied from the first production cycle. The experimental subplots consisted of 16 plants, of which the 4 central ones were used for the evaluations, with a complete border.

Soil water content was determined with the PR2 multi-sensor capacitance probe (Delta-T Devices Ltd, Cambridge, UK) using frequency domain reflectometry (FDR). The FDR probe was calibrated using the sensor output readings obtained in volts (V) and converted into volumetric moisture (θv) through the equations provided by the manufacturer. The data obtained for the depths of 0.10, 0.20, 0.30, 0.40, 0.60, and 1.00 m, corresponding to the electronic sensors of the probe, were correlated with soil water content, determined in disturbed samples by the gravimetric method from saturation to values close to the wilting point (Silva Junior et al., 2013).

In each subplot of the experimental area, three PVC access tubes (⌀ 32 mm) were installed up to a depth of 1.0 m in the soil at a distance of 0.25, 0.50, and 0.75 m from the pseudostem of one of the 4 central plants chosen for readings in different layers. However, the data considered in the study were only those collected up to the 0.60 m layer, since this depth comprises the zone with the highest root density and the highest water extraction, ideal for the installation of sensors (Donato et al., 2015).

To analyze soil water balance, the data were always collected immediately before irrigation and 1 hour after irrigation for a period of three weeks (November 12–14, November 27–29, and December 3–5) in 2019. During this period, the analyzed plants were in the initial stage of flowering. From the values of soil water content, crop ETc was estimated by calculating the components of soil water balance.

Soil water storage was determined using the trapezoid method in the different horizontal points of the soil, i.e., at the distances of 0.25, 0.50, and 0.75 m from the banana plant pseudostem according to the equation of Libardi (1995):

$$h_L = \int_0^L \theta(z)\,dz = \left[0.5\times\theta(z_i) + \sum_{i=1}^{n-1}\theta(z_i) + 0.5\times(z_n)\right]\times\Delta z$$

where: h_L corresponds to soil water storage (cm), θ is the average water content in the considered soil layer (cm^3 cm^{-3}), and Δz is the thickness of the soil layer (cm).

Considering that the probe has data collection modules with intervals of 0.10 m in the 0.0–0.40 m layer and of 0.20 m in the 0.40–0.60 m layer, the data obtained by the trapezoid method in both layers was summed to determine water storage in the entire soil layer.

Water storage variation for each day was obtained by the following equation: $\Delta h = h_t - h_{t-1}$ where: Δh is the variation in soil water storage (mm), h_t is soil water storage at instant t (mm), and h_{t-1} is soil water storage at instant t-1 (mm).

Deep percolation was determined by summing the values obtained at each r distance from the pseudostem using the data from the 0.60 m depth, immediately

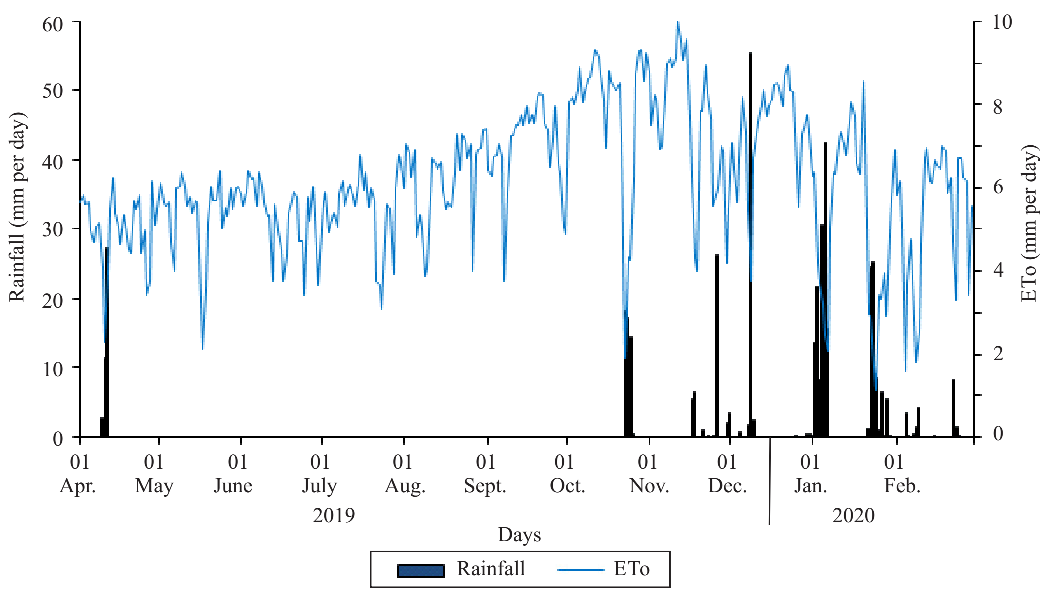

Figure 1. Rainfall and reference evapotranspiration (ETo) recorded during the experimental period from April 2019 to February 2020 in the municipality of Guanambi, in the state of Bahia, Brazil. Source: data collected at the automatic weather station installed in the experimental area of Instituto Federal Baiano.

DOI: 10.1590/S1678-3921.pab2024.v59.03423

below the effective depth of the root system (Coelho et al., 2022), through the following equation:

$$DP = \int_{j+1}^{j+2} q\,dt$$

where: DP is deep percolation, considered the integration of the water flux (q) in a 24 hour period, from the moment immediately before irrigation (j+1) to a time before the next irrigation (j+2); and q is the water flux represented by the FDR probe (cm h^{-1}). This flux was obtained by the equation:

$$q = \frac{\theta - \theta'}{t} \times \frac{V}{A}$$

where: θ ($cm^3\ cm^{-3}$) is the water content in the volume of soil at instant t (hours), θ' is moisture in the volume of soil (V) at instant t+1 (hours), V is the volume of soil (cm^3) corresponding to the sensor (0.1x0.20x0.25 m), A (cm^2) is the area of the section where the probe is inserted into the ground (0.1x0.25 m), and t is the time interval (24 hours).

Among the water balance components evaluated, the following two were disregarded: capillary rise, since the water table of the soil under study is deep; and runoff, because the experiment was carried out in a terrain with a virtually zero slope.

During the experimental period, there was little to no rainfall, so practically all water that entered the soil came from irrigation. On November 25, 26 mm of rain were recorded in the study area and irrigation was resumed on November 27. Considering this scenario, the soil water balance in the root zone of 'Prata Anã' banana was represented by the following equation:

$$ETc = I - (DP + \Delta h)$$

where: ETc is crop evapotranspiration (mm), I is the water depth applied in irrigation (mm); DP is deep percolation (mm), and Δh is the variation of soil water storage (mm).

At the time of harvest, the following production characteristics were evaluated: number of fruits and hands per bunch, mass of hands (kg), and yield of hands (Mg ha^{-1}). Irrigation water productivity (water use efficiency), calculated based on the yields of hands and the applied depths (kg ha^{-1} mm^{-1}), and the blue water footprint (L kg^{-1}) were also estimated.

The obtained data were subjected to normality and homoscedasticity tests and to the analysis of variance. In the case of significant interactions, regression models were fitted for planting densities considering each irrigation depth. In the absence of interactions, the effects of the main factors were studied using the regression analysis for planting densities, and means were compared by Tukey's test, at 5% (α=0.05) significance, for irrigation depths. The used models were chosen based on the following parameters: significance of the beta coefficients by the t-test, magnitude of the coefficient of determination, significance of the mean square of regression, and adequacy to the studied biological phenomenon.

Results and Discussion

The evaluations carried out at harvest in the fourth production cycle of 'Prata Anã' banana showed that the analyzed variables differed significantly for at least one of the evaluated factors and that only water productivity and water footprint for hands varied with the interactions between irrigation depths and planting densities (Table 1). The number of hands, number of fruits, mass of hands, and yield of hands were independently influenced by planting density.

The number of hands and number of fruits per hand decreased with increasing planting densities (Figure 2). From the density of 1,666 to 3,333 plants per hectare, the number of hands reduced from 11.45 to 9.5. Likewise, Magalhães et al. (2020) and Rodrigues Filho et al. (2020) observed reductions in the number of hands in 'Prata Anã' and 'D'Angola' banana, respectively, at the highest densities.

For number of fruits per bunch, a linear model was fitted. At the densities of 1,666, 2,083, and 2,666 plants per hectare, the numbers of fruits per bunch were 189.92, 182.85, and 172.96, respectively, showing a slight reduction from one density to another. However, at the planting density of 3,333 plants per hectare, the number of fruits was 14.9% lower than that at the lowest density. When evaluating cultivar BRS Platina (AAAB), Santos et al. (2019) found a 7.77% decrease in the number of fruits when planting density increased from 1,666 to 3,333 plants per hectare. The angular coefficients of the regressions showed that planting density had a greater effect on number of fruits per bunch, followed by mass of hands and number of hands per bunch.

The increase in planting density from 1,666 to 3,333 plants per hectare induced a linear reduction from 19.68 to 16.68 kg in mass of hands, which represents a decrease of 15.24%. In the same location and using the same spacings, but in the first two production cycles of 'Prata Anã' banana, Magalhães et al. (2020) also observed a decrease in the mass of hands, which varied from 18.92 kg at the density of 1,666 plants per hectare to 15.79 kg at the density of 3,333 plants per hectare. Therefore, even in later production cycles, banana plants can respond positively to an increased planting density when associated with lower irrigation depths. A reduction in the mass of hands with an increased planting density is expected and has been verified by Santos et al. (2019) and Rodrigues Filho et al. (2020) for 'BRS Platina' and 'D'Angola' banana, respectively. However, Siqueira et al. (2021) did not observe any association between mass of hands and planting density when studying 'Prata Anã'.

The yield of hands increased linearly with planting density, from 33.31 to 56.14 Mg ha^{-1} from 1,666 to 3,333 plants per hectare, respectively, representing a 40.7% increase. With an increased planting density, yield is expected to increase since more plants per area produce a higher number of bunches and fruits, as also reported by Santos et al. (2019) and Rodrigues Filho et al. (2020). As in the present study, Santos et al. (2019) and Magalhães et al. (2020) observed that the increase in yield does not negatively affect the commercial characteristics of the banana fruit, such as mass, length, and diameter. Therefore, these findings are an indicative of the benefits of the interaction between a higher planting density and the reduction in irrigation depth even in the fourth cycle when the plant is larger.

The irrigation water productivity of hands increased linearly at the depths of 100 and 50% ETc with the increase in planting density (Figure 3). However, the highest values for this variable were achieved with the irrigation depth of 50% ETc, at the highest planting density of 3,333 plants per hectare. This suggests the possibility of obtaining high yields with a higher planting density and a lower water supply. These results are in agreement with those of Magalhães et al. (2020), who analyzed three irrigation depths (50, 75, and 100% ETc) in the first two production cycles of banana. These findings justify evaluating banana orchards throughout more production cycles.

Water footprint was higher at the irrigation depth of 100% ETc than at 50% ETc, decreasing linearly with the increase in planting density in both cases. Between the lowest and highest planting density, there was a reduction of 38.26 and 43.86% in the water footprint for the 100 and 50% ETc depths, respectively. According to the fitted model, to produce 1.0 kg of banana, an average of 920.24 L of water were required for the 100% ETc depth at the planting density of 1,666 plants per hectare and of 276.05 L kg^{-1} for the 50% ETc depth at the density of 3,333 plants per hectare. Oliveira et

Table 1. Analysis of variance with the respective mean squares and coefficients of variation of the production characteristics evaluated at the time of harvest of 'Prata Anã' banana (*Musa* spp.), cultivated under different planting densities (1,666, 2,083, 2,666, and 3,333 plants per hectare) and irrigation depths (100 and 50% crop evapotranspiration).

Source of variation[(1)]	Degrees of freedom	Mens square					
		Number of hands	Number of fruits	Mass of hands	Yield of hands	Water productivity of hands	Water footprint of hands
ID	1	3.31[ns]	0.12[ns]	4.28[ns]	16.65[ns]	1,343.00**	1,068,086.0**
Block	3	0.27[ns]	360.76[ns]	0.94[ns]	7.69[ns]	0.64[ns]	2,117.0[ns]
Error A	3	0.50	389.12	1.80	16.61	2.36	2,686.0
PD	3	5.84**	1,484.46**	13.72*	786.51**	177.00**	126,517.0**
IDxPD	3	0.65[ns]	152.80[ns]	0.99[ns]	3.28[ns]	82.00**	7,409.0*
Error B	18	0.30	288.82	4.33	29.13	4.58	6,410.0
Total	31						
CV1 (%)		6.70	11.15	7.33	9.29	7.56	9.02
CV2 (%)		5.14	9.61	11.38	12.30	10.54	13.93

[(1)]ID, irrigation depth; PD, planting density; and CV, coefficient of variation. * and **Significant by the F-test, at 5 and 1% probability, respectively. [ns]Nonsignificant.

DOI: 10.1590/S1678-3921.pab2024.v59.03423

al. (2022), when studying the blue water footprint in banana cultivated in the semiarid region of the state of Ceará, Brazil, found values of 780.9, 830.6, and 862.7 L kg^{-1} in the Missão Velha, Jaguaribe-Apodi, and Russas regions; the last two are close to the value found in the present study for the 100% ETc depth. This high amplitude in the obtained results points to the impact of irrigation management practices and planting density on the production processes of the banana crop. Therefore, the evaluation of this indicator allows of generating and validating different strategies that make it possible to develop more efficient and sustainable cultivation systems, as observed in the present work.

The analysis of soil water storage showed that the highest values, ranging from 2.09 to 3.46 mm, occurred in the soil irrigated with 100% ETc, with the highest value obtained at the planting density of 1,666

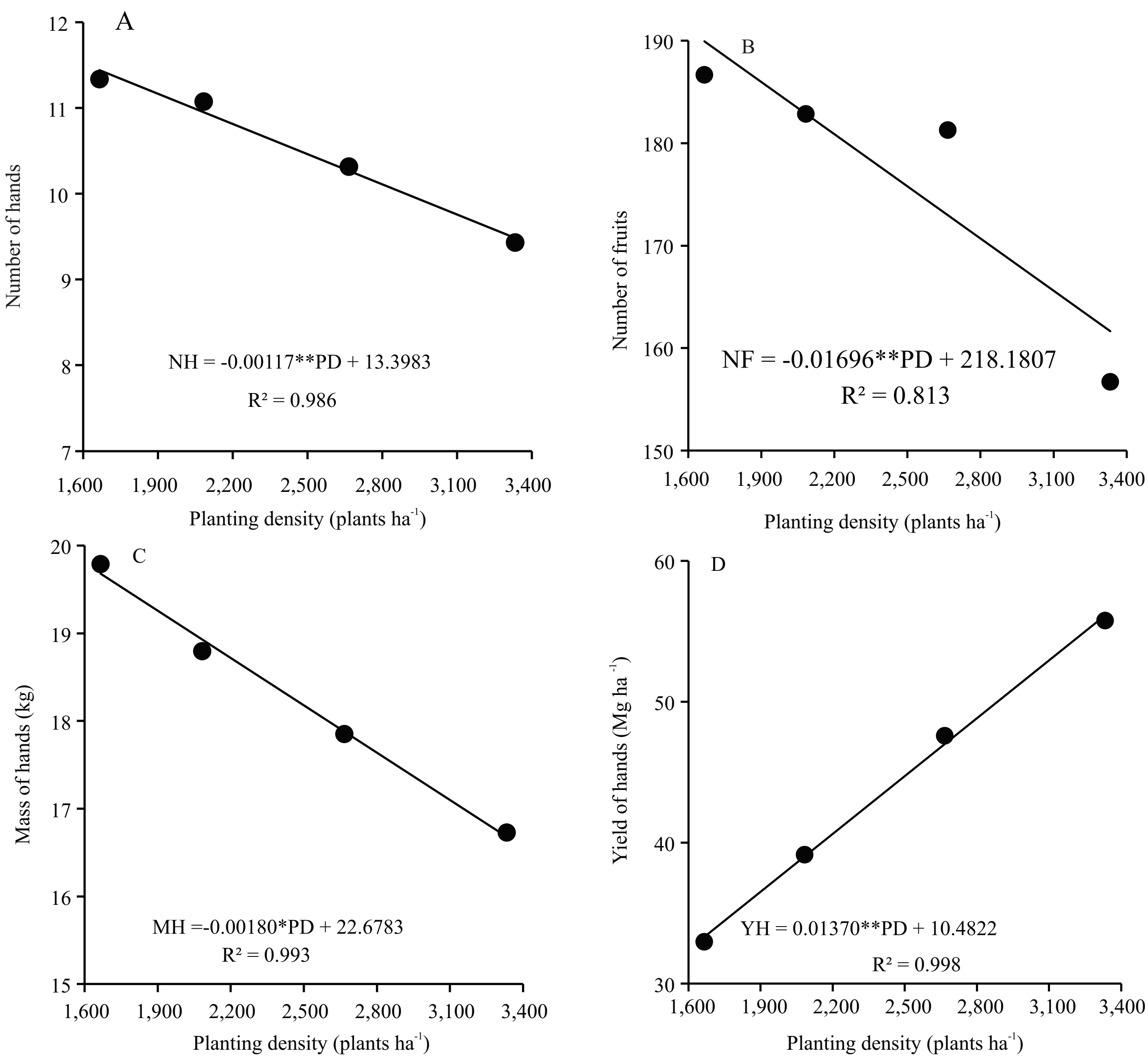

Figure 2. Production characteristics evaluated at the time of harvest in the fourth production cycle of 'Prata Anã' banana (*Musa* spp.), cultivated at different planting densities (1,666, 2,083, 2,666, and 3,333 plants per hectare). NH, number of hands; PD, planting density; NF, number of fingers; MH, mass of hands; and YH, yield of hands. **Significant by t-test, at 1% probability.

plants per hectare in November 12–14 (Table 2). At the 50% ETc depth, the values ranged from 1.24 to 1.71 mm, with the highest variation in soil water storage also occurring in November 12–14 for the planting densities of 1,666 and 3,333 plants per hectare. The average soil water storage at the evaluated planting densities was 2.85 and 1.55 mm at the 100 and 50% ETc depths, respectively. It should be noted that the values for this parameter were always positive in all treatments, which confirms the non-occurrence of water deficit during the experimental period (Silva et al., 2015).

Deep percolation values were very low for both the 100 and the 50% ETc depths. These low values indicate a low loss of water and nutrients from the system to the deeper soil layers, possibly showing the efficiency of the irrigation system and the accuracy of the adopted irrigation management, besides suggesting that the data were obtained under satisfactory moisture conditions for banana plants (Silva et al., 2015).

Based on the soil water balance data, the estimated values of ETc ranged from 7.95 to 12.19 mm per day for the irrigation depth of 100% ETc, with the highest value at the planting density of 1,666 plants per hectare in November 12–14 and the lowest value at the planting density of 2,666 plants per hectare in December 3–5. ETc values close to 12 mm per day are associated with the fruiting stage of the crop, as well as with the evapotranspiration demand of the region. Donato et al. (2016) concluded that, since ETo can reach values higher than 9.0 mm per day in the region, ETc values can be higher than 12.5 mm per day. Under the 50% ETc irrigation depth, the calculated ETc oscillated between 3.71 and 6.20 mm per day at the planting density of 2,666 plants per hectare in December 3–5 and at the planting density of 2,083 plants per hectare in November 12–14, respectively. This shows that, with the reduction of water depths at higher planting densities, gains in water conservation can be achieved by reducing ETc.

The average ETc of the planting densities was 9.72 mm per day for the 100% ETc depth and 4.72 mm per day for the 50% ETc depth, representing a reduction of 51.4%. The ETc values obtained in the present study are above those from 1.00 to 6.00 mm per day found for banana plants in the region of Cruz das Almas, in the state of Bahia, by Silva et al. (2015), who estimated evapotranspiration using the soil water balance method. Similarly, D'Alburquerque Junior et al. (2013) reported ETc values between 2.05 and 3.82 mm per day for banana in the region of Vale do Parnaíba, in the state of Piauí. The findings of the present work, therefore, are an indicative that, even in the fourth production cycle, the water consumption of banana plants under higher planting densities, associated with reduced water depths, can be similar to that of traditional crops.

The crop coefficient, obtained by the ratio between the calculated actual ETc and ETo, varied greatly with the reduction in irrigation depth. The obtained values ranged from 1.27 to 1.34 under the 100% ETc depth and from 0.59 to 0.67 under the 50% ETc depth. Therefore, as there were no differences in banana

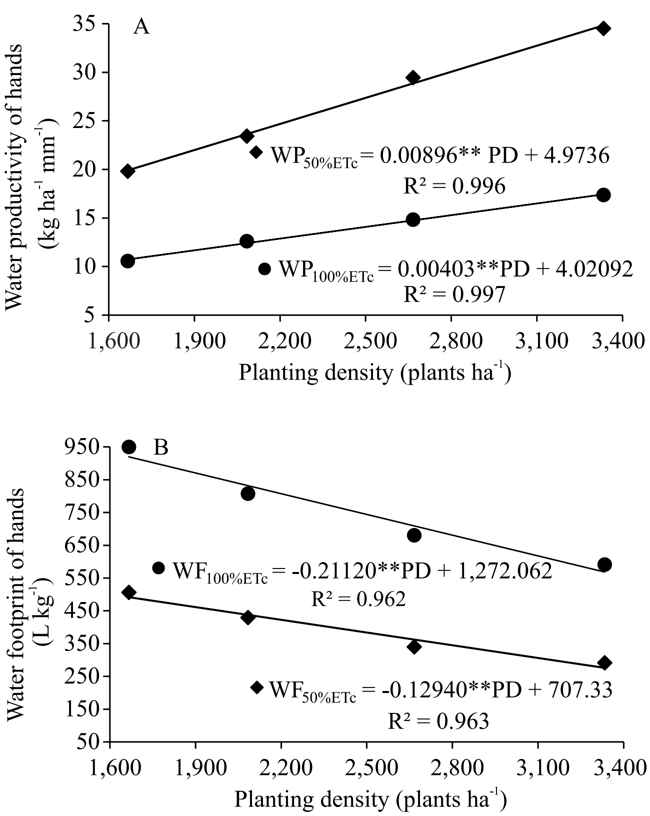

Figure 3. Water productivity (WP) of hands (A) and water footprint (WF) of hands (B) evaluated at the time of harvest in the fourth production cycle of 'Prata Anã' banana (*Musa* spp.), cultivated under different planting densities (1,666, 2,083, 2,666, and 3,333 plants per hectare) and irrigation depths (100 and 50% crop evapotranspiration). PD, planting density; and ETc, crop evapotranspiration. **Significant by t-test, at 1% probability.

Table 2. Average values of the components of water balance in soil cultivated with 'Prata Anã' banana (*Musa* spp.) under two irrigation depths (100 and 50% crop evapotranspiration) and four planting densities (1,666, 2,083, 2,666, and 3,333 plants per hectare) in November 12–14, November 27–29, and December 3–5, 2019[(1)].

Water depth	Planting density	Date	Irrigation (mm)	ETo (mm)	Δh (mm)	DP (mm)	ETc (mm)	Kc (calc)
100%	1,666	Nov. 12–14	15.70	9.31	3.46	0.04	12.19	1.31
		Nov. 27–29	11.67	6.92	2.79	0.03	8.85	1.28
		Dec. 03–05	10.42	6.18	2.09	0.04	8.29	1.34
100%	2,083	Nov. 12–14	15.70	9.31	3.38	0.03	12.29	1.32
		Nov. 27–29	11.67	6.92	2.57	0.02	9.08	1.31
		Dec. 03–05	10.42	6.18	2.56	0.01	7.84	1.27
100%	2,666	Nov. 12–14	15.70	9.31	3.50	0.03	12.17	1.31
		Nov. 27–29	11.67	6.92	2.77	0.03	8.87	1.28
		Dec. 03–05	10.42	6.18	2.44	0.03	7.95	1.29
100%	3,333	Nov. 12–14	15.70	9.31	3.65	0.02	12.02	1.29
		Nov. 27–29	11.67	6.92	2.79	0.02	8.86	1.28
		Dec. 03–05	10.42	6.18	2.14	0.02	8.25	1.34
Mean			12.59	7.47	2.85	0.03	9.72	1.30
50%	1,666	Nov. 12–14	7.85	9.31	1.71	0.02	6.11	0.66
		Nov. 27–29	5.84	6.92	1.56	0.02	4.26	0.62
		Dec. 03–05	5.21	6.18	1.45	0.02	3.74	0.61
50%	2,083	Nov. 12–14	7.85	9.31	1.62	0.03	6.20	0.67
		Nov. 27–29	5.84	6.92	1.51	0.03	4.29	0.62
		Dec. 03–05	5.21	6.18	1.30	0.03	3.88	0.63
50%	2,666	Nov. 12–14	7.85	9.31	1.67	0.02	6.16	0.66
		Nov. 27–29	5.84	6.92	1.65	0.02	4.16	0.60
		Dec. 03–05	5.21	6.18	1.48	0.01	3.71	0.60
50%	3,333	Nov. 12–14	7.85	9.31	1.71	0.02	6.12	0.66
		Nov. 27–29	5.84	6.92	1.73	0.02	4.09	0.59
		Dec. 03–05	5.21	6.18	1.24	0.03	3.94	0.64
Mean			6.3	7.47	1.55	0.02	4.72	0.63

[(1)]ETo, reference evapotranspiration; Δh, water storage variation; DP, deep percolation; ETc, crop evapotranspiration; and Kc, crop coefficient.

productivity under 50 and 100% ETc, it is suggested that the crop coefficient of 0.67 can be used for irrigation management in the fourth production cycle under a high planting density, allowing of an increase in water use efficiency without affecting crop yield.

Conclusions

1. In the fourth production cycle of the 'Prata Anã' banana (*Musa* spp.) plant, the increase in planting density from 1,666 to 3,333 plants per hectare reduces the number of hands, number of fruits, and mass of hands, but increases yield.

2. Under the experimental conditions in the Brazilian semiarid region, the increase in planting density makes it possible to reduce the irrigation depth applied in the fourth production cycle of 'Prata Anã' banana, increasing the yield of hands and water productivity and reducing water footprint.

Acknowledgments

To Fundação de Amparo à Pesquisa do Estado da Bahia (FAPESB) and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for financial support; and to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for financing, in part, this study (Finance Code 001).

References

ALLEN, R.G.; PEREIRA, L.S.; RAES, D.; SMITH, M. Crop evapotranspiration: guidelines for computing crop water requirements. Rome: FAO, 1998. 300p. (FAO. Irrigation and drainage paper, 56).

ATHANI, S.I.; REVANAPPA, R.; DHARMATTI, P.R. Effect of plant density on growth and yield in banana. **Karnataka Journal of Agricultural Sciences**, v.22, p.143-146, 2009.

BORGES, A.L.; COELHO, E.F.; COSTA, É.L. da; TEIXEIRA, A.H. de C. Irrigação e fertirrigação na cultura da banana. In: SOUSA, V.F. de; MAROUELLI, W.A.; COELHO, E.F.; PINTO, J.M.; COELHO FILHO, M.A. (Ed.). **Irrigação e fertirrigação em fruteiras e hortaliças**. Brasília: Embrapa Informação Tecnológica, 2011. p.369-397.

COELHO, E.F.; SANTOS, M.R. dos; DONATO, S.L.R.; REIS, J.B.R. da S.; CASTRICINI, A. Produção e eficiência de uso da água em cultivares de bananeira sob irrigação com déficit controlado. **Irriga**, v.26, p.94-110, 2021. DOI: https://doi.org/10.15809/irriga.2021v26n1p94-110.

COELHO, E.F.; SANTOS, M.R. dos; SOUZA, E. de A.; MELO, D.M. de; CAMPOS, M.S. Root distribution and its relations with soil chemical attributes and yield of banana under fertigation with and without soil covering. **Acta Scientiarum. Agronomy**, v.44, e53296, 2022. DOI: https://doi.org/10.4025/actasciagron.v44i1.53296.

D'ALBURQUERQUE JUNIOR, B.S.; GOMES, E.R.; SOUSA, V.F. de; SOUSA, A. de P. Necessidade hídrica e lâminas de irrigação da bananeira cv. FHIA-18 na região semiárida do Piauí. **Irriga**, v.18, p.756-767, 2013. DOI: https://doi.org/10.15809/irriga.2013v18n4p756.

DONATO, S.L.R.; COELHO, E.F.; MARQUES, P.R.R.; ARANTES, A.M. Considerações ecológicas, fisiológicas e de manejo. In: FERREIRA, C.F.; SILVA, S. de O. e; AMORIN, E.P.; SANTOS-SEREJO, J.A. dos (Ed.). **O agronegócio da banana**. Brasília: Embrapa, 2016. p.45-110.

DONATO, S.L.R.; COELHO, E.F.; SANTOS, M.R. dos; ARANTES, A. de M.; RODRIGUES, M.G.V. Eficiência de uso da água em bananeira. **Informe Agropecuário**, v.36, p.46-59, 2015.

LIBARDI, P.L. **Dinâmica de água no solo**. Piracicaba: Edusp, 1995. 497p.

MAGALHÃES, D.B.; DONATO, S.L.R.; SANTOS, M.R. dos; BRITO, C.F.B.; FONSECA, V.A.; SOUZA, B.S. de. Yield of 'Prata-Anã' banana plants under water deficit and high plant density. **Revista Brasileira de Fruticultura**, v.42, e-046, 2020. DOI: https://doi.org/10.1590/0100-29452020046.

OLIVEIRA, V.R. de; COSTA, R.N.T.; NUNES, K.G.; BARROS, V. da S. Water footprint of banana in the Brazilian semi-arid region. **Revista Ciência Agronômica**, v.53, e20196925, 2022. DOI: https://doi.org/10.5935/1806-6690.20220036.

RODRIGUES FILHO, V.A.; DONATO, S.L.R.; ARANTES, A.M.; COELHO FILHO, M.A.; LIMA, M.B. Growth, yield and gas exchanges of 'D'Angola' plantain under different planting densities. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.24, p.490-496, 2020. DOI: https://doi.org/10.1590/1807-1929/agriambi.v24n7p490-496.

SANTOS, E.F.N.; SOUSA, I.F. de; LEITE, I.V. Regiões homogêneas em Sergipe agrupadas através dos Índices Climáticos. **Revista Brasileira de Meteorologia**, v.4, p.1-13, 2022. DOI: https://doi.org/10.1590/0102-77863740053.

SANTOS, H.G. dos; JACOMINE, P.K.T.; ANJOS, L.H.C. dos; OLIVEIRA, V.Á. de; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A. de; ARAÚJO FILHO, J.C. de; OLIVEIRA, J.B. de; CUNHA, T.J.F. **Sistema brasileiro de classificação de solos**. 5.ed. rev. e ampl. Brasília: Embrapa, 2018. 356p.

SANTOS, M.R. dos; DONATO, S.L.R.; MAGALHÃES, D.B.; COTRIM, M.P. Precocity, yield and water-use efficiency of banana plants under planting densities and irrigation depths, in semiarid region. **Pesquisa Agropecuária Tropical**, v.49, e53036, 2019. DOI: https://doi.org/10.1590/1983-40632019v4953036.

SILVA JUNIOR, J.J. da; COLOMBO, A.; SCALCO, M.S.; SILVA, B.M.; LIMA, P.T. Calibração de sondas de capacitância para determinação de umidade em latossolo vermelho distroférrico. **Irriga**, v.18, p.743-755, 2013. DOI: https://doi.org/10.15809/irriga.2013v18n4p743.

SILVA, A.J.P. da; COELHO, E.F.; COELHO FILHO, M.A. Water extraction variability in the banana root zone affects the reliability of water balance. **Scientia Agricola**, v.72, p.1-10, 2015. DOI: https://doi.org/10.1590/0103-9016-2014-0003.

SIQUEIRA, C.L.; PEREIRA, M.C.T.; NIETSCHE, S.; XAVIER, A.A.; MENDES, A.H.; XAVIER, H.R.A.; GUIMARÃES, R. de S.; LACERDA, D.R.; SANTOS, S.R. dos. Growth and production of 'Prata Anã Gorutuba' banana under different planting densities. **Scientia Agricola**, v.78, e20190031, 2021. DOI: https://doi.org/10.1590/1678-992X-2019-0031.

SOIL SURVEY STAFF. **Keys to soil taxonomy**. 12th ed. Washington: USDA, 2014. 360p.

SOUZA, V.A.P. de; SANTOS, M.R.; ARAÚJO, A.M. de; COSTA, L.T.; DONATO, S.L.R. Root system of 'BRS Platina' banana under irrigation levels and planting densities. **Comunicata Scientiae**, v.12, e3605, 2021.